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ABSTRACT

The paper describes two experiments using the Computational Mathematics Monitoring System (CMMS) with mildly handicapped (educable mentally retarded-EMR and learning disabled-LD) students. In the first study, data is presented on the summative evaluation of the CMMS with 19 Ss. It is explained that evaluation results do not provide clear-cut support for the program, although experimental Ss made gains on the criterion referenced test in four basic math areas. The second study reports on the effects of CMMS on reducing systematic errors in the whole number operations of 36 LD Ss (10-15 years old). Results of the second study are seen to indicate that generalization was occurring in the reduction of systematic errors. Implications of the studies are said to show the effectiveness, to a limited degree, of the CMMS in reducing systematic errors. (CL)

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The Efficacy of a Computational Mathematics Monitoring System for the Minimally Handicapped Child

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Much can be found in the literature concerning systematic progress monitoring systems, particularly to assist teachers with mathematics instruction (Burney, 1976; Crutcher, 1974; Gall, Dunning, & Galussi, 1971; Kerr, 1977; Lipson, 1974; Schoen, 1974). Nevertheless, few progress monitoring systems are reported to have been validated with minimally handicapped populations. Two well designed studies (Burney, 1976; Kerr, 1977) did document the effectiveness of progress monitoring with handicapped populations. Both of these researchers found that monitoring can place a tremendous burden on teachers which often results in only partial implementation of the monitoring procedures. This is particularly unfortunate due to the advantages possible when progress monitoring is utilized.

Several researchers have reported strong gains in academic achievement after a monitoring system was implemented (Bloom, 1978; Burney, 1976; Kerr, 1977; Webb & Cormier, 1972). Authorities state that problems in learning can be detected and corrected through careful monitoring of progress before they become prolonged and the learner's achievement and self-concept are affected (Bloom, 1978; Briggs & Aronson, 1975). More research is needed if these advantages are to be realized on a large scale for many populations of students.

This particular progress monitoring package, "Computational Mathematics Monitoring System" (CMMS) was developed for two major purposes. First, to enable teachers of mildly handicapped students

to present computational math skills in a systematic fashion and enable them to monitor performance and to assist them in writing Individual Educational Plans as mandated by PL 94-142. A second purpose was to make it possible to investigate specific computational errors.

The major purpose of the first investigation was to provide a summative evaluation of CMMS. The effects of the implementation of this progress monitoring system of student gains in mathematical computation were studied. A second investigation was conducted on a different group of subjects to study the effects of CMMS on the reduction of systematic errors. This study will be described following a description of the first.

Summative Evaluation of CMMS

A brief description of CMMS was developed and shared with LD and EMR teachers. Teachers in both programs were asked to volunteer with the understanding that some would be randomly assigned to the experimental condition and those remaining would continue using the current program with the option of using the CMMS the next year if the data warranted. Two LD and two EMR classes participated as experimental groups and two LD and two EMR classes as controls.

The initial group of subjects consisted of fifty-one EMR youngsters and forty-seven LD youngsters. The EMR data was not analyzed for reasons to be discussed later. The final population consisted of nineteen youngsters in the experimental condition and eighteen in the control. Table 1 shows mean age, as of September, 1977, and the race and sex composition of both groups. All youngsters

attended schools serving youngsters from diverse racial and economic

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backgrounds.

All eight teachers received approximately one visit a month from the first author which served to provide feedback on instruction in particular and for those teachers using CMMS, the specifics of implementing that program. This monthly visit was supplemented with visits by the second author as well as a research assistant. These visits enabled us to determine the degree to which the monitoring system was actually being used in the experimental classes.

A detailed Teacher's Guide, as well as all components of the monitoring system, including worksheets, were given to each of the teachers in the experimental classes. The Teacher's Guide provided them with a description of each component and its purposes, steps for implementing the system, and suggestions for assisting students in moving through the program and for remediating computational errors.

In order to fully implement the monitoring system, teachers were asked to utilize seven procedures: (a) administer the Criterion Referenced Test (CRT) prior to the intervention, midway through the school year, and the end of the school year; (b) record mastery of skill levels on a Group Monitoring Chart; (c) determine instructional groupings based on the chart; (d) record percent correct scores on individual student graphs for daily worksheets;

(e) determine instructional needs based on the graphs; (f) record dates of completion of skill levels on individual student folders; and (g) administer worksheets and maintenance probes on a regular basis.

The initial CRT data was used to determine the specific placement of each student on a continuim of basic computational areas of whole numbers, fractions, and decimals. Each teacher was taught a simple coding system that allowed quick recognition of each specific skill level (task area) in all phases of computational math. Teachers in the experimental condition monitored progress of each youngster through daily drill on worksheets containing ten to twenty problems for each specific skill level. Criteria for movement to new skill levels or to maintenance review sheets were provided in the Teacher's Guide.

The Keymath test was also administered to experimental and control classes. Although all subscales were administered, we planned to base our evaluation on four subtests: Addition, Subtraction, Multiplication, and Division. These subtests were chosen because they involved skills which might be expected to be influenced by the CMMS program.

Daily class procedures included the following: The teacher handed each student his or her CMMS folder which included previously completed worksheets on the computational skill level under study, an accuracy graph, and a new worksheet for that day. Each student was expected to study his accuracy graph and the previous days worksheet, ask questions concerning them if need be and remove the new

worksheet from the folder to prepare for work. The teacher, at the same time, praised those who had improved, offered encouragement to those who had not, and answered any questions. Just before work began, the teacher demonstrated the process of computing a particular type of skill level problem, working through the first problem on the worksheet for each student who had difficulties with his particular type of problem, (usually two or three). Then all students were told to begin work. After ten or fifteen minutes, time was called and worksheets and folders collected. The teacher or an aide graded the worksheets the same day and recorded scores on graphs. The date was written on each student's folder beside the appropriate skill level for all students who met the criteria for mastery. The appropriate box on the Group Monitoring Chart was shaded for each of these students. (This chart was displayed in the classroom at the discretion of the teacher.) The final daily procedure was to place new worksheets in the folders for those students who needed them. (Worksheets were stapled in packets of three each, so this step was necessary no more often than one out of every three days per student.)

As students progressed through the study of specific skill levels as determined by the Criterion Referenced Test, Maintenance Probes were administered in place of the daily worksheet according to schedule. Any other diagnostic, motivational, or remedial procedures pertaining to mastery of the skill levels were determined by individual teachers.

RESULTS

Because of the visits and the close monitoring inherrent when performance is graphed, it became apparent that the EMR experimental teachers were not implementing the program. Teachers in the EMR program lack aides and had difficulty with recording data and monitoring progress. Due to the low degree of implementation the decision was made not to analyze the data for EMR classes.

The loss of the EMR experimental group necessitated that we employ a one-way analysis of variance. Treatment condition was the independent variable and the sum of Addition, Subtraction, Multiplication, and Division from the Keymath test was the dependent variable. This variable was named Math Computation. An analysis was conducted with Pre-Math Computation as the dependent variable to satisfy ourselves that the groups were comparable at the outset of the project. The results of the analysis indicated that the experimental group had higher computation scores prior to the CMMS program (t (35) = 3.50 $p < .05$).

Table 2 shows means and standard deviations for experimental

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and control groups for each variable. The unexpected high level of performance of the experimental group on the pretest created an analysis problem. Obviously, an analysis of posttest scores was inappropriate because the groups were not comparable prior to the math program. The decision was made to employ analysis of covariance to adjust posttest scores for the initial difference in pretest

performance. Since further inspection revealed an eleven point difference in IQ between the groups, IQ as well as pre-Math Computation were used as covariates, and post-Math Computation was used as the dependent variable. The results of the covariance analysis revealed no significant difference in math computation ability between the groups ($F(1,36) = .013$ $p > .90$).

To determine the influence of the Computational Math Program on each computational area four additional analyses of covariance were conducted. In each treatment condition was the independent variable. The first involved the use of IQ and pre-addition as covariates and post-addition as the dependent variable. No significant difference between the groups was observed ($F(1,33) = .326$ $p < .57$). In the second analysis IQ and pre-subtraction were used as covariates and post-subtraction was used as the dependent variable. No significant differences were observed between experimental and control subjects on this variable ($F(1,33) = .003$ $p < .95$). In the third analysis IQ and pre-multiplication were used as covariates and post-multiplication as the dependent variable. The difference between the groups on this variable was not significant ($F(1,33) = 3.127$ $p > .08$). The last analysis involved division. IQ and pre-division were used as covariates and post-division as the dependent variable. No significant difference was observed between this group either ($F(1,33) = .114$ $p > .73$).

To determine whether the experimental youngsters gained in math skills, a series of t tests were conducted using the scores on the Criterion Referenced Test as the dependent variable. A separate

t test was conducted for addition, subtraction, multiplication, and division. Means and standard deviations appear in Table 3.

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In one experimental class youngsters had not worked far enough in the program to arrive at multiplication and division so these youngsters were eliminated from comparisions involving multiplication and division.

Significant gains were obtained in each area. For addition, (t (19) = 4.45) for subtraction, (t (19) = 7.65) for multiplication, (t (10) = 4.81) and for division, (t (10) = 4.66). All of these are significant at the one percent level.

DISCUSSION

Unfortunately, the pattern of results does not provide the clearcut support for the Computational Math Program for which we had hoped. The experimental youngsters made gains on the Criterion Referenced Test in the four basic math areas. However, experimental youngsters did not score higher than control youngsters on the Key-math test when initial pretest and IQ differences were taken into account.

Two glaring errors were made by the second author which must be acknowledged. Prior experience with LD classes indicated considerable homogeneity across classes. Stated more directly, the average WISC IQ usually does not vary more than three or four points between classes. The two classes with the highest mean IQ by far in the

whole LD program both, unfortunately, were randomly assigned to the experimental group. After the groups were selected but prior to the intervention the comparability of the groups on this variable should have been determined. This is a problem which can occur whenever the class is the unit selected rather than the individual. The second mistake was the choice of the Keymath test which may be unsatisfactory to assess math progress of LD youngsters.

Goodstein, Kahn, and Cawley (1976) observed that because EMR children obviously do not make the same rapid progress in math as nonretarded children, the Keymath may be an inappropriate measure of their achievement gains. The same may be said for LD children. The implication for this study is that differences in item difficulty of various grade levels are greater for LD children than for non-LD children. As a result, the test may lack items at an intermediate level of difficulty for LD children which makes the Keymath test or, very likely, any wide range achievement test low in power to discriminate achievement gains for LD children. This, of course, would be reflected in the scores of both experimental and control groups.

At the very least, the Keymath test does not measure precisely what the Computational Math Program teaches. The structure of the math program employed causes youngsters to work on one math skill until it is mastered. For example, youngsters work on addition until they reach criterion then they move on to subtraction. Since the four Keymath subtests were used with all youngsters whether or not they had actually received instruction, quite a few youngsters were tested over material which they had not reached in the program.

The fact that not all teachers implemented the program to the fullest extent is consistent with reports from other studies on monitoring (Bloom, 1978; Burney, 1976; Kerr, 1977; Webb & Cormier, 1972). As this system required fewer time consuming activities, we had hoped to illeviate this problem. Obviously, more research is needed in this area.

The significant gains in computation areas must be emphasized. A mean range of five skills mastered in addition on the pretest, to nine on the posttest, to three skill levels mastered in subtraction on the pretest, to eight on the posttest, one skill level mastered in multiplication on the pretest, to five on the posttest, and no skill levels mastered in division on the pretest, to two on the posttest was obtained. Furthermore, many students expressed enthusiasm and pride in observing their progress on both graphs and the Group Monitoring Chart. Systematic errors as well as other types of errors were pinpointed and mastery of skill levels occurred.

In conclusion, suggestions for future research on CMMS are warranted. First, the Keymath test should be replaced with one more appropriate for evaluating this program, perhaps the Criterion Referenced Test alone would suffice. Second, the effects on student achievement of the elimination of some of the monitoring procedures for teachers without aides should be investigated. The use of adjunct monitoring resources such as peer monitoring should also be studied.

The effects of progress monitoring on the reduction of systematic errors is of importance as well and is addressed in the description of our second investigation.

The Effects of CMMS on Reducing Systematic Errors

Research on systematic errors--those errors in which a consistency or pattern can be found in three out of five problems--in math computation suggests a great need to pinpoint types of errors made and provide remediation. Cox (1973a, 1973b, 1974, 1975) found that a substantial number of errors in computation are systematic and will continue to occur for long periods of time unless instruction focuses specifically on their remediation. Our clinical data shows even higher percentages of systematic errors are made by handicapped students. In order to diagnose systematic errors a number of problems of each specific skill level must be analyzed. This can be difficult to do to any real degree unless computation is given to students on worksheets organized by skill levels. CMMS provides the record keeping materials and skill level worksheets necessary for this kind of monitoring. The purpose of the second study was to observe the effects of CMMS in reducing systematic errors in whole number operations for skill levels studied and contrasted to those not studied.

Five hypotheses were investigated concerning results of pre- and posttests. First, the gains in the reduction of systematic errors for skill levels studied is greater than the gains in the reductions of systematic errors in skill levels not studied. Second, a significant gain will be found in the reduction of systematic

errors in skill levels studied. Third, a significant gain will be found in the reduction of systematic errors not studied. Fourth, the variance of gains in reduction of systematic errors will be less for skill levels studied in contrast to skill levels not studied. Fifth, a significant correlation will be found between the gains in the reduction of systematic errors for skill levels studied and not studied.

METHOD

Thirty-six learning disabled students ranging in age from ten to fifteen participated in one of three math classes taught by the first author who utilized the CMMS program. The program was implemented exactly as in the first study including the length of time spent with the materials each day as well as the teaching methods utilized.

Due to the individualized study of skill levels, a rather complicated method of determining gains in the reduction of systematic errors had to be used. First, the number of items each student attempted on the CRT was computed separately for pre-and post-, studied and not studied skill levels. Second, all incorrect items were analyzed to determine the actual number of systematic errors made by each subject for pre- and post-, studied and not studied skill levels. Third, the percent of systematic errors was determined for each subject pre- and post-, studied and not studied skill levels by dividing the total items attempted by the total items with systematic errors. Then the gains for the percent of systematic errors reduced was determined by subtracting the

percent of systematic errors on the posttest from the percent on the pretest for skill levels studied and not studied.

RESULTS and DISCUSSION

Only seventeen of the thirty-nine students attempted problems from both skill levels studied and not studied. In other words, some students were eliminated because they did not attempt any problems involving skill levels they had not studied, either on the pre- or posttests or both. A few subjects were eliminated because they had studied all whole number skills prior to taking the post-test.

To determine whether the mean gain for the percent of systematic errors reduced in those skill levels studied was greater than for those not studied, a Repeated Measures design was employed. The mean gain for the percent of systematic errors reduced in skill levels studied was greater than for skill levels not studied ($F(1,16) = 9.28$), which is significant at the .05 level.

A close look at the raw data revealed that those subjects who made the highest positive and negative gains in the percent of systematic errors for skills not studied had actually studied a greater number of skill levels than those subjects with lower negative or positive gains. This indicates that the monitoring procedures discriminated quite well in some cases and poorly in others between subjects who had remediated systematic errors and those who had not. Further observation revealed that subjects tended to make fewer systematic errors on skill levels most recently studied. It may well be that more emphasis needs to be placed on

maintenance procedures for many subjects.

A t-test was employed to determine whether the mean gain for percent of systematic errors reduced for skill levels studied was significantly different from zero. The same kind of analysis was conducted for skill levels not studied. No significant gain was found for skill levels studied (t (16) = 1.89). A significant gain for percent of systematic errors reduced in skill levels not studied was found at the .05 level (t (16) = 2.30).

These results indicate that generalization was occurring in the reduction of systematic errors. It should be noted that gains in skill levels of addition, subtraction, multiplication, and division were at least as great for these subjects as those in the first study. The lack of significance of the gains in the percent of reduction of systematic errors in skill levels studied indicates that criteria for mastery need to focus more directly on systematic errors rather than concentrating exclusively on mastery of skill levels.

A test for Homogeneity of Related Variances was employed to determine whether the variance of gains for the percent of systematic errors reduced was less in skill levels studied than in those not studied. The variance in reduction of systematic errors for skill levels studied was found to be less than for skill levels not studied (t (15) = 5.31) which is significant at the .05 level. Examination of the raw data shows that less dramatic negative and positive gains were made on skill levels studied.

Pearson Product Moment Correlation was computed between gains in systematic error reduction for skills taught and for skills not taught. A correlation of .67 was obtained which is significant

at .01 level with 15 degrees of freedom. A relationship does appear to exist between systematic errors reduced in skill levels studied and systematic errors reduced in those not studied. It may be possible then, to teach some types of problesm and have generalization help in the remediation of those not taught. The implications of this would be of great value in the teaching of the handicapped.

The effectiveness of CMMS in reducing systematic errors was shown to a limited degree. Further research needs to be conducted to determine what changes in the CMMS monitoring procedures might result in more effective reduction of systematic errors. With the existence of a high degree of this type of error in computation for the minimally handicapped, further investigations are certainly warranted.

TABLE 1

Age, Sex, and Race of Youngsters
In Experimental and Control Conditions

Group	Mean Age*	Percent Male	Percent White
Experimental	9-0	88	69
Control	9-9	74	32

*Expressed as years and months

TABLE 2

Means and Standard Deviations for
Experimental and Control Groups

VARIABLE NAME	GROUP			
	EXPERIMENTAL		CONTROL	
	X	SD	X	SD
IQ	97.67	9.77	86.79	5.43
Pre-Addition	8.3	1.0	6.2	1.6
Post-Addition	9.8	1.9	7.8	2.4
Pre-Subtraction	6.4	1.7	4.9	1.0
Post-Subtraction	7.6	2.3	6.4	2.5
Pre-Multiplication	3.0	2.4	1.8	1.6
Post-Multiplication	4.8	2.6	2.3	1.4
Pre-Division	2.2	1.5	1.8	.4
Post-Division	2.6	1.9	2.3	.7
Total Pre-Computation	20.0	5.43	14.7	3.5
Total Post-Computation	24.78	7.31	18.8	5.5

TABLE 3

Means and Standard Deviations of
Experimental Subjects on the
Criterion Referenced Test

Subtest	Pre-test		Post-test	
	Mean	SD	Mean	SD
Addition	7.10	2.51	9.55	1.34
Subtraction	3.40	2.74	8.25	2.33
Division	1.36	1.85	4.81	2.75
Multiplication	.85	1.10	2.00	1.61

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PRE & POST MEAN SCORES OF SKILL LEVELS MASTERED
AS DEMONSTRATED ON THE COMPUTATIONAL MATHEMATICS
CRITERION REFERENCED TEST